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The Silvereye (*Zosterops lateralis*: Aves: Zosteropidae): a review

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Abstract

Silvereyes have been pests of fruit crops since the last century but research to combat the problem has been minimal. They have a catholic diet with most documented items being arthropods from stomach contents. Nectar is an important food item in Western Australia because an abundant supply limits damage to crops of grapes. Migration in the eastern states is well known but only after the banding of more than 100 000 individuals. The banding of 36 000 in Western Australia has shown little evidence of systematic movements. The study of agonistic behaviour has suggested that aggressive behaviour is disadvantageous at feeding stations. Dominant individuals, however, survive better through winter and are more likely to breed. The study of a colour-banded population in New Zealand in 1939-40 provided information on breeding and territorial and vocal behaviour. Adult Silvereyes moult completely post-nuptially and partly pre-nuptially. Juveniles hatched early moult similarly but late-hatched juveniles' first moult is arrested and then the pre-nuptial moult is a complete moult. Variation in plumage colouration was first used to suggest the eastern migration and has been used with varying degrees of success to predict the sex of an individual. Body weight is lowest in the morning and 7% heavier in the late afternoon. Weight has been shown to be negatively correlated with daily air temperature and southern birds are heavier than northern ones. Maximum weight is attained during winter.

Introduction

Although Silvereyes are well known to amateur and professional ornithologists, many who have worked with them find them frustrating subjects to study because they are small, well camouflaged and secretive and, therefore, difficult to observe. In addition, the extent of our present knowledge is not great enough to allow an interpretation of some aspects of their biology that have been under investigation for some time. For instance, many amateur bird-banders in Western Australia are frustrated by the low recapture and recovery rate of their banded Silvereyes and by the fact that banded individuals do not seem to visit between banding stations that are as close as two km any more than between those that are 20 km apart. The resolution of such problems will undoubtedly take place as more data accumulates. In the meantime, it is valuable and encouraging to realise that many years of patient and dedicated work has provided substantial information about this animal. The purpose of this paper is to demonstrate that our knowledge of the Silvereye is greater than many may realise as well as to provide a basis for further research.

I have divided the information into seven sections: pest status, diet, movements, social behaviour, moult, colour variation and body weight.

Pest Status

Silvereyes have been well known to fruit growers in Western Australia ever since the days of the early settlements. Dalkeith Farm, described as a fruit garden extending along the Swan River and worked by James Gallop from 1877, was an important property to the new colony because of the produce it supplied to the north-west ports and Albany, as well as to Perth and Fremantle. By 1886 Silvereyes had become troublesome amongst the fruit and two Aborigines were employed to shoot the birds, more than 8 500 being shot in one year (Oldham and Williams 1980). Later, Aborigines were employed to frighten the birds away from the crops by beating kerosene tins with sticks (Hallack 1891, Oldham and Williams 1980). At least 20 000 Silvereyes were shot on this property and in another orchard near Bunbury 1 200 were shot in one day (Serventy and Whittell 1976, p. 403). Milligan (1904) claimed that 20 000 Silvereyes were often shot in a single orchard in a season.

Silvereyes were thought to be such a serious pest that in 1897 the Bureau of Agriculture proposed a bonus for their destruction of one shilling per 100 birds. The bonus was dependant upon a similar sum being paid by the Local Agricultural Societies (Anon. 1897).

In 1902 a deputation from the Bunbury district met with the Minister for Lands advising him of the considerable damage the Silvereye was causing to fruit in their area and that a recent meeting at Bunbury had resolved to ask the Minister to send an officer "to inquire into the habitat of the bird." They, too, wanted the Government to provide money for a bounty payment (Anon. 1902).

In 1904 a bonus of two shillings per 100 was proposed in a letter to the Minister for Lands by a frustrated fruit grower (Anon. 1904). He claimed that Silvereyes, as well as damaging fruit, destroy beneficial insects such as ladybirds which would otherwise have saved his citrus crop from a bad infestation of scale insects. Amongst his suggested methods for exterminating the species was that the Department's ornithologists should look to the possibility of parasitising the Silvereye. Milligan (1904) replied in defence of Silvereyes maintaining their usefulness in controlling insects that would otherwise be a problem. He proposed that a study be initiated to analyse the gut contents of Silvereyes to determine exactly what insects they do eat, as well as suggesting several methods to reduce the damage caused by Silvereyes to fruit. Newman (1924) supported the role of Silvereyes in maintaining the "balance of nature" by destroying unwanted insects. He claimed that the bulk of food found in the Silvereyes' stomachs was insects, particularly scales and aphids. He did not say if this latter claim was the result of the study proposed by Milligan (1904).

Apart from the limited use of a promising acoustic device developed by Knight and Robinson (1978a and 1978b), methods for controlling Silvereyes in fruit crops have advanced little from that of shooting to picking the crop early.

Diet

It is now well documented that Silvereyes are insectivorous as first reported by Cleland (1911 and 1912) and later summarised (Cleland *et al.* 1918). Matthiessen (1973) and Matthiessen and Springett (1973) found that Silvereyes ate arthropods of eight orders when they were feeding in and near potato crops in the Manjimup-Pemberton area of southwest Western Australia. The most common food was Lepidopteran larvae (mainly potato moth, *Phthorimaea operculella*), Coleopteran larvae and Hemiptera. In years when a particular food item was most abundant in the potato crops, that food item was found to be most common in the Silvereyes sampled. This shows that Silvereyes adjust their foraging behaviour to take the most abundant food item. In addition to this, Springett and Matthiessen (1975) showed that Silvereyes preferred to eat the larger fourth instar of the potato moth when larvae densities were low but, when larvae densities increased, the smaller third instar became increasingly attractive. This occurred despite equal abundance of both instars and indicates that Silvereyes respond to prey on a cost/reward basis. When prey numbers are low the birds prefer the larger items because the energy cost of capturing the smaller prey is too great with respect to the energy reward. When the prey is abundant no such preference is shown because the smaller items are common enough for their capture to require less energy expenditure.

In a New Zealand apple orchard, Moeed (1979) found that the food of Silvereyes in winter consisted of 14 orders of arthropods as well as earthworms, fruit and seeds. Lea and Gray (1936) and Rose (1973) also listed arthropods that they found in stomachs of Silvereyes.

It is generally known that Silvereyes have a wide range in diet, but little has been published on their diet other than arthropods. In South Africa the Yellow White-eye (*Zosterops senegalensis*) has been seen eating very strong red peppers that "pack a powerful punch" when added to a Chadian curry (Elliott 1977). Silvereyes regularly eat soft fruits, particularly grapes, in southern Australia and in late summer can be a nuisance in vegetable gardens eating such things as capsicums and tomatoes. In March, 1980, near Margaret River, Western Australia, two birds that I had banded were found in a bucket of milk where they had drowned, presumably whilst trying to drink the milk. Nectar is a favourite food of Silvereyes although confirming data is difficult to collect for such small birds.

Cage experiments have shown that they prefer sugar water more than various fruits (Rooke unpub.) and Ford (1979) reported observations of foraging Silvereyes that gave a ratio of nectar to insect feeding of 20:80. There is strong circumstantial evidence that Silvereyes have a preference for nectar over fruit. In southwest Western Australia, when the marri (*Eucalyptus calophylla*) produces large amounts of nectar during the fruit ripening season, Silvereyes are not seen in orchards and vineyards. Conversely, when the nectar crop is poor, Silvereyes cause great damage to the fruit (Robinson 1960, Rooke in prep.). Additional circumstantial evidence is that Silvereyes carry heavy loads of eucalypt pollen during times when marri flowers and the birds are absent from vineyards (Rooke unpub.). Observation of feeding as well as analysis of stomach content of Silvereyes in southwest Western Australia are showing the variety of food items taken. As well as 11 orders of arthropods, fruit or berries are taken from 18 species of plants, and nectar is taken from eight species (Rooke unpub.).

Hopper and Burbidge (unpub.) observed 57 plant species from which Silvereyes have been seen to eat nectar, berries, insects or seeds. Forty-nine of these are records of nectar feeding.

Table 1 summarizes the orders of arthropods that Silvereyes are known to eat.

Movements

My banding of Silvereyes around the Margaret River area of southwest Western Australia is indicating that the local population does not move far. Out of 11 000 birds banded so far only one has been recovered at a distance—at Manjimup 100 km ESE. All other recoveries have been within 50 km (Fig. 1).

Banding work at Middlesex near Manjimup, by Dick and Molly Brown has shown a few distant movements (one 267 km N, one 114 km NNE, two 100 km WNW) but other recoveries have been within 35 km (Dick and Molly Brown 1978-79;

Table 1

Orders of arthropods that Silvereyes are known to eat.

Order	Reference						
	1	2	3	4	5	6	7
Collembola					x	x	x
Blattodea						x	x
Orthoptera							x
Psocoptera						x	
Phthiraptera							x
Hemiptera	x	x	x	x	x	x	x
Thysanoptera	x					x	x
Neuroptera	x				x		
Coleoptera	x	x		x	x	x	x
Diptera	x			x	x	x	x
Lepidoptera	x	x	x	x	x	x	x
Hymenoptera	x	x		x	x	x	x
Pseudoscorpionidea						x	
Araneida	x	x	x		x	x	x
Opiliones						x	
Acarina	x					x	
Amphipoda						x	

1—Cleland *et. al.* (1918); 2—Lea and Gray (1936); 3—Rose (1973); 4—Matthiessen (1973); 5—Matthiessen and Springett (1973); 6—Mceed (1979); 7—Rooke (unpubl. data).

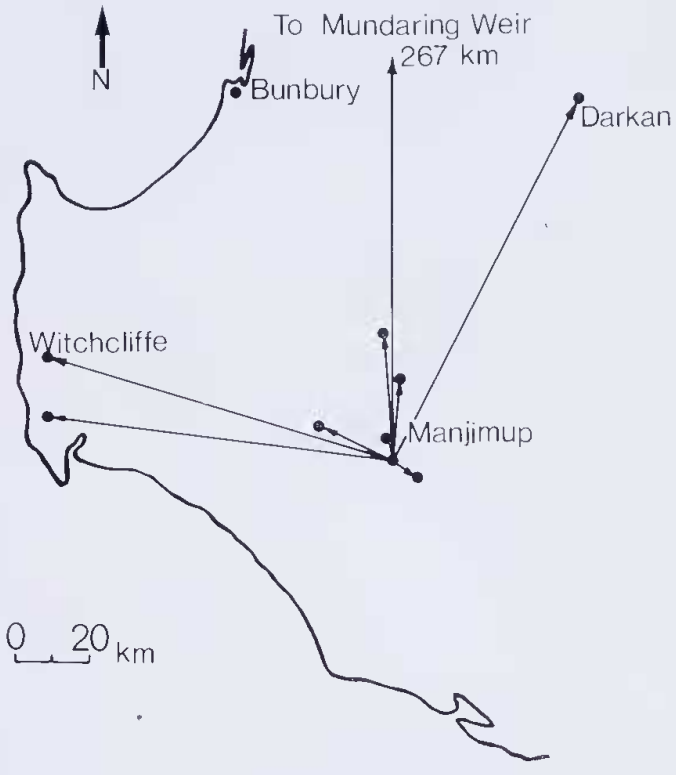

Figure 2.—Movements of Silvereyes from Middlesex, Western Australia. (from Brown 1978-9, 1979-80)

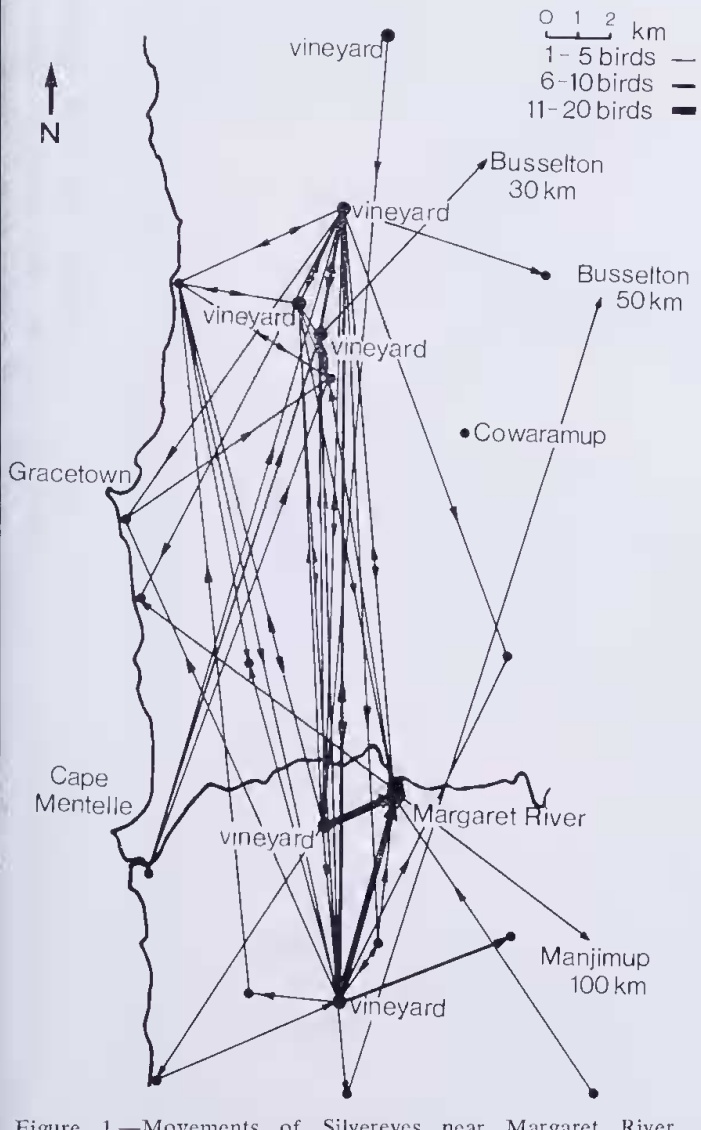

Figure 1.—Movements of Silvereyes near Margaret River, Western Australia. (Rooke unpubl. data)

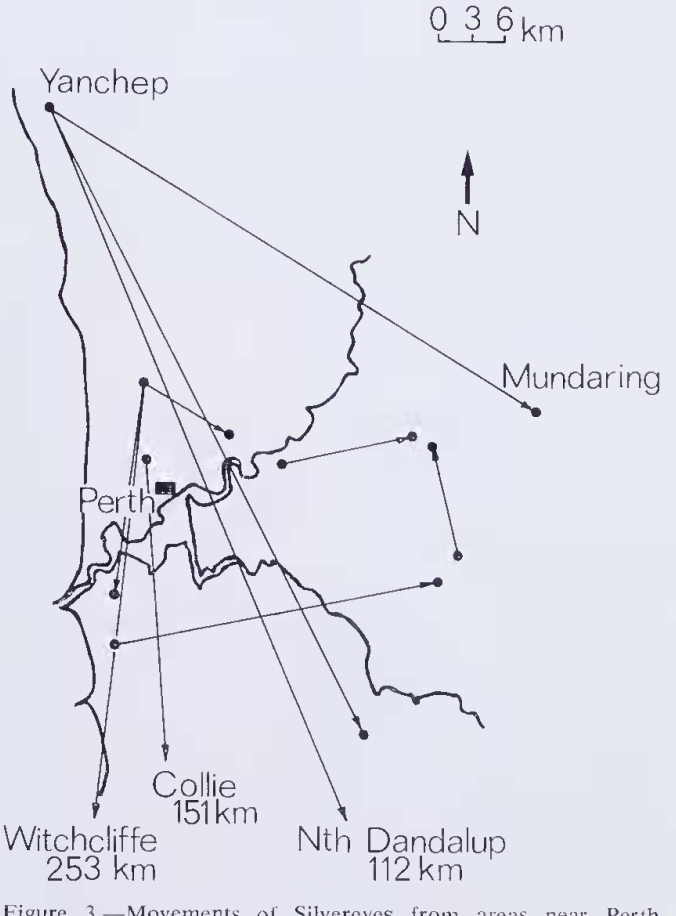

Figure 3.—Movements of Silvereyes from areas near Perth, Western Australia. (P. de Rebeira, unpubl. data)

1979-80) (Fig. 2). The Browns have banded approximately 10 000 Silvereyes but their efforts have failed to show any systematic movement.

Over the past 10 years, a number of people in and near Perth have banded approximately 15 000 Silvereyes. They have demonstrated several long movements of 100 to 300 km, all of which have been recovered south from where they were banded (Fig. 3). It may be that the birds which move south are a particular category of bird (e.g. juvenile) or perhaps recoveries have been made in the regions south rather than north of Perth because there are more settlements south and therefore more people to find banded Silvereyes. In addition to this, small flocks of Silvereyes have been observed moving southward along the coast in late summer. However, there is no evidence to suggest a return, northward movement (P. de Rebeira, pers. comm.).

Western Silvereyes may be more sedentary than some of their eastern counterparts, although such a conclusion may be rather hasty when viewed with the experience of the banding work in the eastern states. In 10 years, more than 100 000 birds were banded in the eastern states and the recoveries showing the long-distance movements amounted to only 75 (45 moving 50-300 km and 30 moving more than 300 km) (Lane 1972). This is a mere 0.00075% of the total birds banded and is a good example of the enormous effort required to substantiate such a phenomenon. Figure 4, from Hitchcock (1966, p. 11) shows some of these movements.

The idea of migration in eastern Australia was first suggested by Keast (1958) after he had noted the systematic arrival and departure of Tasmanian-type birds, as well as having caged Tasmanian-type birds to demonstrate that their plumage colouration was not changeable as proposed by others. Keast also noticed that the migration was partial because a considerable number of Silvereyes remained in Tasmania all winter.

Observations of Tasmanian-type Silvereyes in New South Wales during winter were also reported by Lane (1962a) and Swanson (1968) and in SE Queensland by Robertson (1971). The migration idea started to receive support by the movement of banded birds between Tasmania and the eastern coast of New South Wales (Lane 1962b, Liddy 1966). Substantial movement occurs at night, northward in autumn and early winter and southward in late spring/early summer (Lane and Battam 1971), although movement continues during the day at lower altitudes (Lane and Battam 1971, Vincent 1978). (Other progressive reports of the Co-operative Silvereye Project are listed in Lane (1972). Some individuals of the eastern Silvereye population, however, are sedentary (Bradley 1963, Liddy 1966, Swanson 1968, Lane 1972) and Lane (1972) suggested two discrete breeding populations one migratory and the other sedentary. The data do not support such a simple explanation for the Tasmanian-type Silvereyes, because some individuals migrate in some years but not in others (Mees 1974). In addition, it is not the juvenile class only that migrates because old birds constitute a large proportion of the migrants *(op. cit.)*.

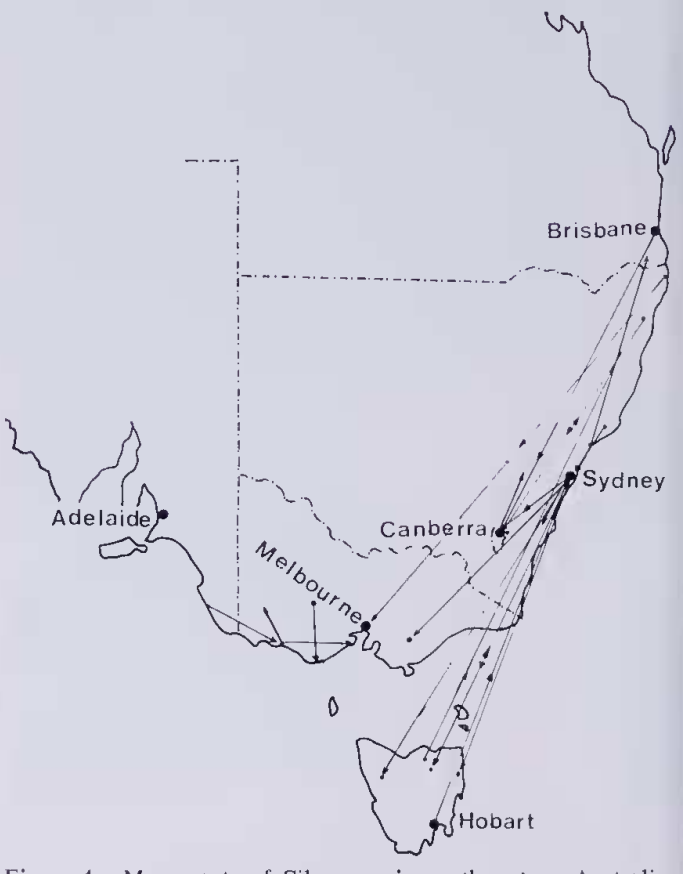

Figure 4.—Movements of Silvereyes in south-eastern Australia. (from Hitchcock 1966)

Fleming (1943) suggested that the Silvereyes in New Zealand do not migrate but that large winter flocks form from the aggregation of the breeding population of the district, and the flocks then disperse over a wider area. This conclusion is supported by the banding work reported by Marples (1944).

Localised movements may be made by particular age classes because Keast (1958) showed that only juvenile Silvereyes moved into vineyards near Sydney whilst the adults remained in the breeding areas. It remains to be shown that this phenomenon is more widespread.

Social behaviour

The social behaviour of Silvereyes has been studied in some detail in various locations by Kikkawa. At Dunedin, New Zealand, Kikkawa (1961) studied aggressive behaviour at a feeding station and in an aviary. He identified five types of aggressive behaviour which serve to establish and maintain the social hierarchy of a group but which, at a concentrated source of food such as the feeding station, seem to be disadvantageous both to the dominant and subordinant birds. Although there were numerous feeding stations in the Dunedin area which were likely to influence the natural population (Kikkawa 1960), Kikkawa (1961) argued that aggressive behaviour would be advantageous to the majority of birds in a less crowded situation.

The aviary birds behaved very aggressively when first caged or when new birds were introduced, but after two weeks of undisturbed occupancy, aggressive behaviour was reduced.

The study of the social hierarchy of winter flocks of Silvereyes was continued at Armidale, New South Wales (Kikkawa 1968). The birds showed the same agnostic displays as those in New Zealand and the southern migratory birds tended to dominate the locals as did males to females. The dominance hierarchy in caged birds did not appear to depend on the weights of the individuals. Territorial behaviour was induced by separating pairs into small cages and then when the small cages were connected, to allow free access to all birds, the original group social hierarchy was evident. This behaviour suggested that the social hierarchy of the winter flock may be important in determining the success of establishing a territory at the beginning of the breeding season.

A more detailed study of the agonistic behaviour of caged Silvereyes was undertaken by Williams *et al.* (1972). They used a numerical technique to analyse the postures of individual birds and, by so doing, were able to identify four of the five behavioural classes originally postulated by Kikkawa (1968), viz: the aggressive bird, the intermediate bird, the submissive bird and the inactive or subordinate bird. Their method failed to identify the dominant bird class. Their results suggested that agonistic behaviour of the flock is initiated largely by a single bird and perhaps influenced by humidity. The social hierarchy appeared to exist at two different levels; one stable hierarchy between groups of birds and another secondary level within each group that is weaker and changeable.

Kikkawa (1977) briefly summarised his earlier work on Silvereyes as a background to describing his work with Silvereyes on Heron Island, Queensland. Between 1965 and 1969 he colour-banded individuals at the beginning of each winter and recorded aggressive behaviour between them. With these data, and by censusing the birds at the end of winter, he found that dominant individuals survived better than submissive ones.

Additional work by Kikkawa and his postgraduate students (Kikkawa *et al.* 1975; Kikkawa 1977) showed that the population on Heron Island does not fluctuate markedly from year to year and, even when the population is severely reduced by cyclones, mortality of the remainder of the population is consequently reduced because of lowered competition for food. The population recovers to its previous density in the next breeding season.

Kikkawa and his students *(op. cit)* studied the breeding success of individuals of various behavioural categories and found that, in years of high density, significantly more pairs high in dominance nested and many first year birds, particularly submissive ones, failed to breed. Independent young were likely to be similar to their parents in dominance status.

The most recent report about the work on Heron Island Silvereyes (Kikkawa 1980) analysed in greater detail the survival through winter between 1965 and 1969 of individuals of different dominance classes. The results showed that socially dominant individuals were more likely to survive their first winter and that juveniles born earlier in the breeding season were more likely to be dominant. Body weight at the start of winter was not significant in affecting a bird's survival through winter. Dominant birds were considered to be more likely to survive because of their superior right of access to food.

Kikkawa's work emphasizes the important difference between dominance and aggressiveness. Dominant individuals (i.e. those that win agonistic encounters) are not always very aggressive and do not spend much energy fighting. On the other hand, aggressive individuals spend much time and energy fighting but but do not always win encounters.

The first published study of colour-banded Silvereyes was carried out in New Zealand by Fleming (1943). He worked mainly on his own property of 0.5 ha during 1939 and 1940. The breeding season was from mid-October until late February or early March with some pairs having three broods in one season. Some individuals and pairs used the same territory and nesting-tree in successive seasons although territorial behaviour did not exist during winter when the birds formed flocks that moved more widely. Fleming provided data about mating, nest-building, egg-laying, hatching, fledging, reproductive success and juvenile mortality. He studied some details of vocal behaviour and touched on the complexities of territoriality.

Moult

Swanson (1971) studied Silvereyes in her backyard in a Sydney, New South Wales, suburb and provided important details about the moult of free-flying birds. The main post-nuptial moult occurs from January to April and is a complete moult in adult birds and juveniles that are hatched early in the breeding season. Juveniles hatched later in the breeding season may commence moulting in their first autumn but this is arrested by the onset of winter and is completed before breeding in the following spring. The pre-nuptial moult of adult birds is mainly a replacement of head feathers. Swanson substantiated the earlier work of Keast (1956), the latter supporting his findings with details of the histology of the thyroid and experiments that demonstrated that changing day-length is the probable environmental factor affecting the timing of the moult. Marples (1945) found that Silvereyes in New Zealand also moult in spring and autumn.

Colour variation

Individual variation in the colour of plumage of Silvereyes has received some attention since Keast (1958) first used such a distinction to infer that Tasmania Silvereyes migrated to the mainland. Robertson (1972) analysed the colour of undertail, throat and flank of Silvereyes in Queensland, and found that the undertail colour decreases in intensity from northern to southern birds. Kikkawa (1963) found that the flank colour of Silvereyes in New Zealand could be used to determine sex, males having a darker or more reddish flank. He suggested that Australian Silvereyes could be sexed on the basis of the colour of the flank but this was not supported

by McKean (1965) or Mees (1969). Serventy and Whittell (1976) note that, for Western Australian Silvereyes, the male has brighter yellow on the throat than the female. My observations in the Margaret River area suggest that it may be possib.e to make such a distinction only if a known pair is being considered because the variation in intensity of the throat colour between males and between females is considerable.

Body Weight

The weights of New Zealand Silvereyes have been analysed on a seasonal and diurnal basis by Marples (1945). He found a diurnal weight fluctuation of 7% with the weight lowest in the early morning and heaviest in the late afternoon. The mean daily weight showed an inverse correlation with the mean daily air temperature. The New Zealand Silvereyes were heaviest in winter which is similar to the data obtained by Dick and Molly Brown (pers. comm.) near Manjimup, Western Australia. McKean (1965) suggested that southern Silvereyes may be heavier than more northern ones, but realised that the issue is complicated by the accumulation and/or expenditure of fat reserves by individuals that have migrated or may be about to migrate. Walker (1964) weighed Silvereyes at Turramurra, New South Wales and, identifying the origin of individuals on the basis of throat and flank colour, found that average weight increased from northern to southern birds.

Conclusion

A great deal of interesting and useful information has been accumulated about numerous aspects of the life of the Silvereye in the Australian and New Zealand regions. Whilst much of this work has been thorough and painstaking, it is clear that there are many unanswered questions.

We know little of the dynamics of the bird's natural food supply and its relationship to movements and consequent damage to crops. Aspects of the bird's physiology may demonstrate why it is such a pest in fruit crops. We know little of the reproductive potential, juvenile recruitment and actual population size, nor of how human agricultural practices affect the population. Studies are needed to determine the age structure of populations in various localities and habitats, to determine whether different classes of birds are involved in different activities. We do not know whether the adult breeding class ever interferes with human activities or whether it remains in natural, undisturbed areas. Answers to these types of questions would allow not only a better understanding of the population dynamics of the species but also a rational assessment of the conflict that this bird presents between agricultural productivity and conservation of natural resources.

We need to known much more about the basic biology of the Silvereye and, because the large number that have been banded suggests that the poulation is large, a concentrated effort by many workers together is likely to be successful in elucidating the broader issues.

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